1348042

PATENT SPECIFICATION

(11) 1348042

(21) Application No. 24355/71 (22) Filed 19 April 1971
(31) Convention Application No. 73997 (32) Filed 24 Aug. 1970 in
(33) Japan (JA)
(44) Complete Specification published 13 March 1974
(51) International Classification B01F 3/12//13/00
(52) Index at acceptance
B1C 14 19A1 4 6 D1D D3B

(19)

(54) APPARATUS FOR UNLOADING PULVERIZED MATERIAL IN TANK

(71) We, MITSUI SHIPBUILDING & ENGINEERING CO. LTD., a corporation organised under Japanese Law, of 6-4, 5-chome, Tsukiji Chuoku, Tokyo, Japan, do hereby declare the invention for which we pray that a patent may be granted to us and the method by which it is to be performed to be particularly described in and by the following statement:—

The present invention relates to apparatus for discharging pulverized material from a container by transforming the material into a slurry.

Generally, pulverized material such as pulverized ore is loaded into a tanker in the form of a slurry which then has the water removed so that a substantially solid mass remains and is stored as such in the tanker. However when the material is to be discharged from the tanker, it is usually again transformed into slurry.

It is an object of this invention to provide improvements in apparatus for discharging pulverised material from a container by transforming the material into a slurry.

According to the present invention there is provided apparatus for discharging a mass of pulverised material from a container having an opening in its bottom said apparatus including a sump to be positioned below the opening, a rotor projecting upwardly from the sump so that it can extend into the tank opening when the sump is positioned below said opening, a nozzle rotatable with the rotor and so mounted at the upper end of the rotor that the nozzle can be selectively directed over a predetermined angular range in a vertical plane, and a pumping and piping system for supplying water at high pressure through the rotor to the nozzle from which the high pressure water is to issue as a jet impinging on the pulverised material to reduce the latter to a slurry.

An embodiment of the present invention will now be described, by way of example only, with reference to the accompanying drawings wherein:—

Fig. 1 is a schematic diagram of conventional apparatus for discharging tanks;

Fig. 2 is a schematic diagram of discharging apparatus embodying the present invention;

Fig. 3 is a schematic diagram of part of the apparatus shown in Fig. 2;

Fig. 4 is a vertical section of part of the apparatus shown in Fig. 2;

Fig. 5 is a cross-section taken on the line A—A in Fig. 4; and

Fig. 6 is a graph of the factors affecting slurry concentration during a typical tank-emptying operation.

Reference will first be made to the conventional apparatus shown in Fig. 1. A sump 2 is provided centrally at the funnel-shaped bottom of a tank 1, and a rotatable cylinder 3 extends upwardly through the sump. At the upper end of the cylinder 3 is a nozzle 4 from which high pressure water is jetted against a mass of pulverized material 5 in the tank while the cylinder 3 is rotated. The jetted water impinges on the pulverized material 5 which is reduced to a slurry which flows down into the sump 2 from where the slurry is discharged through a pipe 7 along with low pressure water introduced through an inlet 6. The slurry is finally discharged by the action of a slurry pump 8.

In this conventional apparatus:

(1) the angle θ formed by the jetting direction of the nozzle 4 with respect to the horizontal plane is constant;
(2) the rotational frequency ω of the vertical cylinder 3 is constant or uncontrolled;
(3) the amount of high pressure water jetted from the nozzle and the amount of low pressure water are not controlled;
(4) no control of the slurry surface level in the sump is made.

On the other hand, the condition of the mass of pulverized material in the tank varies as the discharging process proceeds, in that the angle ε between the direction of the jet of high pressure water and the surface of the pulverised material mass which is formed by the water jet, the velocity u at which the

[Price 25p]

water jet sweeps the surface of the material mass, and the distance between the nozzle 4 and the surface of the material 5 all vary in an uncontrolled manner which results in a wide variation in the concentration of the slurry received in sump 2. Such variation of slurry concentration becomes particularly excessive when ε and u are incorrect. An excessive increase in slurry concentration may result in blockage of the sump 2 or of the pipe 7 with pulverized material. This blockage will cause retardation of discharge of water injected into the tank and idle rotation of the slurry pump 8. In order to avoid such difficulties, there is no alternative but to carry on the operation by reducing the average concentration of the slurry. This requires a great amount of water and large power consumption as well as a large capacity tank for receiving the slurry.

Now, the present invention will be described with reference to Figures 2 to 6 of the drawings in which the same reference numerals as those in Fig. 1 are used to denote like parts. Referring to Figs. 2 to 6 a slurry forming device 10 has a sleeve 11 mounted to extend through the bottom of the sump 2, and rotatably fitted in the sleeve 11 is a cylinder 12 which is kept watertight in the sleeve by means of seal rings 13. The lower end of the rotary cylinder 12 is connected to a rotary shaft or stub axle 15 supported by thrust bearings 14 mounted on a supporting casing. At the upper end of the rotary cylinder is rotatably mounted a transverse shaft 16 which carries the nozzle 4. A pinion 17 fixed to the shaft 16 meshes with a rack 18 vertically slidably mounted within the rotary cylinder 12. Also, at the top of the rotary cylinder 12 a cap 20 is provided to protect the nozzle 4. The nozzle 4 projects through a slit 21 in the cap 20 so that the nozzle can swivel in a vertical plane.

A rod 22 coupled to the rack 18 extends slidably and rotatably through the rotary shaft 15 and is coupled to a piston 25 in a hydraulic cylinder 24 through a thrust coupling 23. Thus, vertical movement of the piston 25 causes a corresponding movement of the rod 22 and a rack 18 such that the nozzle 4 swivels in a vertical plane through an angle θ within a range of ± 90 degrees about the axis of the shaft 16. A pulley 26 is fixed to the rotary shaft 15 and is driven by means of a belt 27 which extends round a pulley 29 driven by a motor 28, so that motive force produced by the motor 28 is transmitted through the rotary shaft 15 and the rotary cylinder 12 to the nozzle 4 to cause it to rotate in the horizontal plane.

High pressure water is pumped from a tank 31 (Fig. 2) by a pump 30 through valves 32 and 33 and an inlet 34 into an annular chamber 35 in the sleeve 11. From the chamber 35 water flows into the rotary cylinder 12 through apertures 36 formed in the cylinder 12 and the water is then ejected from the nozzle 4.

Low pressure water pumped from the tank 31 by a pump 37 is divided into two parts one of which is passed through a pipe 40 into the sump 2 from the inlet 6, while the other part is passed through a valve 38 and a pipe 41 and flows into the sump 2 through small openings or apertures 42 formed along the entire upper periphery of the sump 2 to prevent deposition of the pulverized material on the sump wall surface. Low pressure water is also injected from a nozzle 43 directed toward the discharge pipe 7 provided in the sump to expedite discharge of the slurry from the sump through the discharge pipe.

At the top of the tank 1 there is mounted a first detection rod 45 for detecting the level of pulverized material 5 in the tank. The detection rod is pivoted at 46 and a mid portion thereof is coupled to a vertically movable rod 47, the vertical position of the rod 47 being detected by a potentiometer 48. There is also provided a second detection rod 50 which is vertically movable, with its vertical position being detected by a potentiometer 51. Both potentiometers 48 and 51 transmit signals to a speed governor 52 of the motor 28 and to a servo valve 53 of the hydraulic cylinder 24. The speed governor 52 determines the rotational frequency of the motor 28 in dependence on the signal from the potentiometers. The servo valve 53 determines the pressure of oil supplied to the cylinder 24 in dependence on the signal from the potentiometers so as to adjust the piston 25 and the rod 22 to the required position about which the nozzle 4 can swivel.

A typical discharging operation will now be described.

First, the valve 54 is opened and the low pressure water pump 37 and the slurry pump 8 are actuated. Then the servo valve 53 is manually operated to move the piston 25 to its uppermost position so that the angle θ of the nozzle 4 is at $-90°$ (the nozzle 4 points directly downwards) and then the high pressure water pump 30 is put into operation. Both high pressure water and low pressure water are fed at full rate while gradually adjusting the nozzle angle θ from $-90°$ to $0°$, whereby the pulverized material in the sump 2 is completely discharged.

Then, the nozzle angle θ is increased to $+90°$ where the nozzle is directed upwardly and a high pressure water jet is ejected therefrom, whereby a narrow conical opening or space is formed above the nozzle extending to the upper surface of the pulverized material mass. The configuration of the mass at this stage is shown by chain lines in Fig. 2. At this time, the free end of the detector rod 45 is in contact with the middle part of the surface 5a of the pulverized material mass,

BEST AVAILABLE COPY

and when the opening is formed at this part, the detector rod moves as the material supporting it is washed away. This produces a change of potentiometer signal which causes the speed governor 52 and the servo valve 53 to alter the nozzle direction and rotation.

It will be understood that the pulverized material mass is gradually broken down by the water jet to form a substantially conical face tapering towards the nozzle. It is to be noted that the nozzle is controlled in such a way that it forms an angle θ 5° to 20° smaller than the angle ϕ formed by the conical face of the mass, that is, θ has a value of $\phi-(5$ to $20°)$. When the upper surface of the pulverized material mass descends below a certain level, it is no longer possible to detect the surface level with the detector rod 45. Thus, thereafter the detector rod 50 is used in combination with the potentiometer 51 to determine the control of the governor 52 and the servo valve 53. In such a way the angle ϕ of the substantially conical face is gradually reduced and finally reaches the value ϕf corresponding to the slope of the tank bottom. The rate of flow of the high pressure water Wh is adjusted by means of an adjusting valve 32 according to the value of the concentration of material 5 in the slurry detected by a slurry density meter 55 disposed in the discharge pipeline connected to the slurry pump 8. More specifically, the rate of flow of high pressure water is decreased when the detected concentration of material 5 in the slurry is higher than a set value, but increased when the concentration is lower than the set value (the material 5 is assumed more dense than water).

The flow rates of high pressure water and low pressure water are detected respectively by a high pressure water flow meter 56 and a low pressure water flow meter 57 and the flow rate of the high pressure water is controlled by a flow rate controlling valve 32 and the flow rate of the low pressure water is controlled by the valve 38, such that the sum of Wh and Wl is substantially constant. If the slurry density in the sump 2 or in the pipe 7 between the sump and the slurry pump 8 is excessive so that the flow resistance of the slurry is excessive the slurry level in the sump rises, and when it exceeds a certain level, it is detected by a level gauge 58. The detection by the gauge 58 causes the feed of high pressure water to be stepped temporarily by closing the valve 33. Thereby, the low pressure water attains its maximum flow rate and carries away the blocking material and when the surface level in the sum declines thereafter, the high pressure water supply system is returned to normal operation.

The rotational frequency ω of the rotary cylinder 12 is controlled by means of speed governor 52, in dependence on the factors such as the angle ϕ detected by the detector rods 45 and 50, in such a way that the sweeping velocity U of the high pressure jet on the face of the material 5 is substantially constant. In the final stage of the discharging operation, the face angle ϕ of the face of the pulverized material mass approximates to the slope angle ϕf of the tank bottom face and the rate of flow to the sump of the slurry produced becomes smaller and smaller. Therefore, the apparatus must be designed so that the angle ϕf between the tank bottom face and the horizontal plane is larger than the critical slope angle corresponding to a slope down which material will just fail to cascade from a stationary start position (in the case of iron sand or pulverized iron ores such an angle is about 17°).

Now, the control of each parameter in the discharging operation will be discussed with reference to Fig. 6 where their variation over the time of the discharging operation is shown.

The operation for reducing the pulverized material in the tank into slurry and discharging it from the tank may be divided into the following three steps:

A. The step of breaking down the mass of pulverized material.

B. The step of carrying the broken down material to the sump. This step is accomplished through a combination of the following two effects:—

(a) Dropping of the material down to the sump due to gravitation; and

(b) Carrying of the material in the flow of water returning to the sump.

C. The step of transferring material from the sump to the slurry pump by adjusting the slurry density with low pressure water.

Considering the discharging operation to be divided in the above manner, it is found that the following conditions must be met to obtain a constant and uniform concentration: (1) That the forming of the slurry proceeds with the above-said three steps A, B, and C, being conducted in a well-balanced manner.

The value of ϕ varies from 90° to ϕf. In the early stage where the value of ϕ is large, the actions of steps A and B are brisk and therefore the action of step C lags behind, resulting in increase of slurry density and blockage of the sump and/or other discharge pipe lines. In this stage, therefore Wh is kept low while Wl is maximised as seen in Fig. 6 so as to obtain a good balance between the actions of A and C. On the other hand, near the end of the operation where $\phi=\phi f$, the actions of A and B are sluggish to cause reduction of the slurry density so that in step C, the amount of high pressure water Wh is increased while the amount of low pressure water is reduced and no restriction of slurry density is effected. However, the increase of Wh does not entail a proportional increase in the slurry flow velocity in the tank which is

related to the flow resistance of the material 5 so that it is necessary to keep the angle ϕf of the bottom face greater than critical slope angle.

(2) That the moment-by-moment variation of the amount of break-down is kept to a minimum.

If the rate of break-down fluctuates widely from moment to moment, there is a danger of causing a blockage. In order to limit the fluctuation, it is necessary to keep the value of $\phi-\theta$ within the range of about 5 to 20°. If the value of $\phi-\theta$ is too great, the angle of the washed face may become negative intermittently, causing a discontinuous crumbling rather than a substantially constant removal of material from the mass in the tank so that there would be a wide variation of the amount of pulverized material broken down from one moment to the next. It is also necessary to keep the sweeping velocity U of the high pressure water jet substantially constant. If the velocity U is too small there may be perforation of the mass surface by the water jet, causing an excessive increase in the local value of $\phi-\theta$ giving rise to the risk of a crumbling or fall-in phenomenon. This results in wide variation of the slurry density.

It has been found that the discharging apparatus described above and embodying the present invention has the following advantages:

(1) There is minimal risk of causing a blockage by slurry or pulverized material.

(2) The variations of density and flow rate are limited to a small range, so that variation of loading forces is small, thus allowing minimization of the size of instruments used and piping capacity.

(3) The average slurry density can be kept relatively high, keeping down the amount of water in the slurry and minimising the necessary capacities of the means for receiving the slurry.

(4) The operation of forming the slurry is simplified and also the discharging operation is automated, thus realizing a saving of labour.

(5) The time required for the discharging operation is shortened compared with using the conventional apparatus shown in Fig. 1.

WHAT WE CLAIM IS:—

1. Apparatus for discharging a mass of pulverised material from a container having an opening in its bottom, said apparatus including a sump to be positioned below the opening, a rotor projecting upwardly from the sump so that it can extend into the tank opening when the sump is positioned below said opening, a nozzle rotatable with the rotor and so mounted at the upper end of the rotor that the nozzle can be selectively directed over a predetermined angular range in a vertical plane, and a pumping and piping system for supplying water at high pressure through the rotor to the nozzle from which the high pressure water is to issue as a jet impinging on the pulverised material to reduce the latter to a slurry.

2. Apparatus according to claim 1 wherein means are provided for automatically adjusting the angle of the nozzle in the vertical plane in dependence on the detected level and/or configuration of the mass of pulverised material.

3. Apparatus according to claim 2 wherein said adjusting means is such as to keep the nozzle upwardly inclined to the horizontal by an angle which is less than an angle detected as corresponding to the slope, relative to the horizontal, of a cone tapering towards the nozzle and having a conical surface assumed to be that of the mass of pulverised material formed by the action of the high pressure water jet from the nozzle.

4. Apparatus according to claim 3 wherein the slope angle of the cone is detected by means arranged to be sensitive to the level of pulverised material at a constant radius from the nozzle.

5. Apparatus according to claim 3 or claim 4 wherein the angle of the nozzle is maintained within a range of 5° to 20° less than the detected cone slope angle.

6. Apparatus according to any one of claims 2 to 5 wherein means are also provided to control the rate of rotation of the rotor in co-operation with the nozzle angle adjusting means.

7. Apparatus according to claim 6 wherein said co-operation is such that the jet issuing from the nozzle sweeps over the pulverised material at a substantially constant speed.

8. Apparatus according to any one of the preceding claims wherein means are provided for supplying water at relatively low pressure to the sump to assist in discharging the slurry from the sump, through a slurry discharge system.

9. Apparatus according to claim 8 wherein said low pressure water supply means include an arrangement of inlets around the upper perimeter of the sump for washing down the walls of the sump and means arranged to direct a flow of water towards a discharge opening in the sump forming an inlet to the slurry discharge system.

10. Apparatus according to claim 8 or claim 9 wherein means are provided to maintain a predetermined relation between the supply rate of high pressure water to the nozzle and the supply rate of low pressure water to the sump.

11. Apparatus according to claim 10 wherein said slurry discharge system includes means sensitive to the constituent proportions of the slurry, said proportion sensitive means being arranged to control the ratio of the supply

rate of high pressure water to the nozzle to the supply rate of low pressure water to the sump so as to reduce the difference between the actual and the required constituent proportions of the slurry.

12. Apparatus according to claim 11, as appendant to claim 6 or claim 7, wherein the proportion sensitive means is also arranged to control the speed of rotation of the rotor.

13. Apparatus according to any one of the preceding claims wherein means, sensitive to the level of slurry in the sump, are arranged to shut off the supply of water to the nozzle when said slurry level exceeds a predetermined value.

14. Apparatus according to any one of the preceding claims wherein said rotor includes a hollow cylindrical upper portion having inlet means in its side wall capable of continuously receiving hgh pressure water supplied through a sleeve mounted on the cylindrical portion and relative to which the rotor is rotatable.

15. Apparatus according to claim 14 wherein a longitudinally movable shaft extends through the cylindrical portion and has a rack mounted at one end adjacent the nozzle, the latter having a pinion secured to it and so arranged to co-operate with the rack that longitudinal movement of the shaft causes the nozzle to pivot in its vertical plane.

16. Apparatus according to claim 15 wherein the shaft is arranged to be moved by hydraulic means and the cylindrical portion forms a longitudinal extension of a stub axle through which said shaft extends to a piston-cylinder arrangement for moving the shaft.

17. Apparatus according to any one of the preceding claims wherein the nozzle projects from a vertical slit in the side of a protective cap mounted on the rotor.

18. Apparatus for discharging a mass of pulverised material from a container having an opening in its bottom substantially as described herein with reference to Figs. 2 to 6 of the accompanying drawing.

19. A storage container for storing a mass of pulverised material, said container having an opening in its bottom and apparatus for discharging the mass of pulverised material according to any one of the preceding claims.

MARKS & CLERK
Chartered Patent Agents,
19 Royal Exchange Square, Glasgow G1 3AE
Agents for the Applicants.

Printed for Her Majesty's Stationery Office, by the Courier Press, Leamington Spa, 1974.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

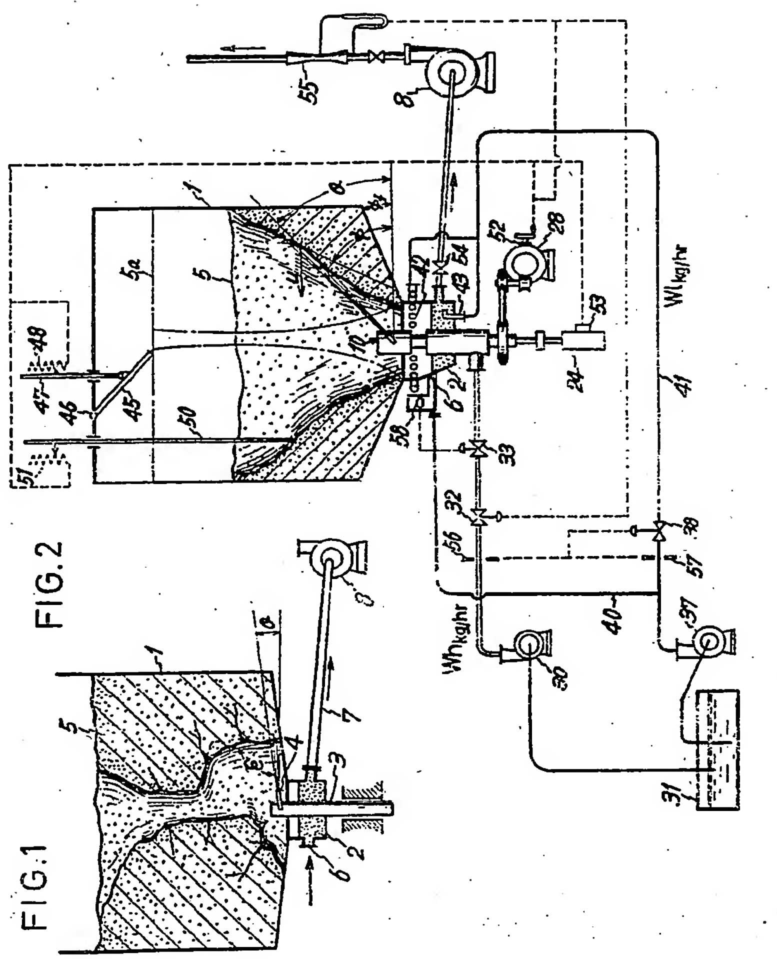

FIG.1

FIG.2